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CONTENTS.

M. E. G. Evans

The Life History of *Atomaria ruficornis* (Marsh.) (Col., Cryptophagidae)

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TRANSACTIONS OF THE SOCIETY FOR BRITISH ENTOMOLOGY

VOL. 14 NOVEMBER 1961 PART IX

The Life History of *Atomaria ruficornis* (Marsh.) (Col., Cryptophagidae)

By M. E. G. Evans

(Zoology Dept., University of Manchester)

Atomaria ruficornis (Marsh.) is a small, fungus-feeding beetle of 1·2 mm. to 1·6 mm. in length. It is commonly found in woodland litter, compost heaps and other accumulations of vegetable detritus. Only a few species of Cryptophagidae have been studied with regard to their life history, and these have mainly been economically important members of the Cryptophaginae (Hinton & Stephens, 1941; Hinton, 1945). In the Atomarinae, Erichson (1848) gave a brief description of the larva of *A. nigripennis* (Kugelann), but the only adequate description of an *Atomaria* larva is that of *A. linearis* Steph. by Newton (1932). No pupa of a member of the Atomarinae appears to have been described previously.

Methods

In rearing *A. ruficornis* in the laboratory it was necessary to simulate its natural habitat, i.e. darkness, a high humidity and the absence of extreme temperatures. A variety of moulds probably form the natural food of the adult beetle, and both adults and larvae were found to eat fungal hyphae in laboratory cultures.

Newton (*l.c.*) noted that it was difficult to induce *A. linearis* to oviposit in captivity. He substituted moist black filter paper for soil in order to facilitate the search for the minute eggs and young larvae. In studying the life history of *Cryptophagus acutangulus* Gyll., Hinton & Stephens (1941) used petri-dishes and test-tubes containing cultures of *Penicillium* and *Botrytis cinerea* Pers. on potato agar. This proved unsuccessful in the case of *A. ruficornis* because the larvae stuck to the mould and, being unable to move, died of starvation. Woodroffe (personal communication) suggested that the best way of obtaining mass cultures of the larvae was to use jars of wheat meal with a layer of wet cotton wool at the bottom. He noted that although providing ideal conditions for breeding it does not allow easy observation. In view of the relatively small numbers of *A. ruficornis* available, cultures of the beetle were set up in 2 by 1 inch or 3 by 1 inch specimen tubes, each of which initially held ten beetles. The cork of each specimen tube was penetrated by a short length of glass tubing to allow adequate aeration. The

tubing was capped with fine mesh gauze to prevent the escape of any beetles. A pad of wet cotton wool placed at the bottom of the tube was covered by a disc of black blotting paper, and the latter was also used to line the tube. The interior of the tube was kept dark and damp, and beetles were prevented from coming into contact with drops of water, and thus being immobilised by the surface film.

A small quantity of wheat bran (about half an inch deep) was placed in the tube on the base paper. The bran quickly grew a variety of moulds and the wheat husks provided a refuge for the larvae, especially the early instars. Although several of the ten specimens put into a culture tube soon died, it was possible to keep some beetles alive for several months. In the spring and autumn, ten laboratory cultures were started, normally with copulating pairs, and several dozen eggs were laid in each of the cultures. However, larvae and pupae were obtained in only three cultures. The cultures were maintained at a room temperature of about 68° F.

The Behaviour of *A. ruficornis* in cultures

The mating behaviour of the adult beetles has been described elsewhere (Evans, 1961). The eggs were apparently laid anywhere on the surface of the blotting paper. They were laid singly and did not appear to be attached in any way to the substratum. Hinton & Stephens (1941) noted that in *Cryptophagus acutangulus* the eggs are laid singly without any attempt at concealment. These authors observed that the eggs were quickly covered by hyphae.

The larvae were often found hidden inside the wheat husks. This applied particularly to the early instars; the last instar larva would frequently be found clear of the bran and eating mould growing on the side paper of the culture tube. It was observed that all larval instars were actively negatively phototactic, on being transferred to a petri-dish. They would retreat from a unidirectional light source until under cover. This behaviour is correlated with their increased activity in bright light. In very dim light, much less activity was observed. In a petri-dish containing blotting paper supporting a thin growth of mould, the larvae ate voraciously and soon cut a clear area around themselves.

One or two days before pupation, the larvae became less active until they became "torpid". In this pre-pupal phase, the larvae contracted considerably in length, until they had about the same proportions as the succeeding pupa. The larvae pupated in a dark enclosed position. They were found in wheat husks or under the base paper of a petri-dish. It was noted that when a pupa was disturbed, it moved its abdomen actively from side to side. On emergence, the imago (callow) was a very light buff colour, and took about a week to attain the normal adult

colour of dark brown, the apical third of the elytra being rather lighter.

In these cultures adults were reared from larvae, but owing to the difficulty of observing the life history, it was normally not possible to follow the life cycle from one instar to the next. In the laboratory, eggs laid in October and early November gave rise to adults six to seven weeks later. In the spring, most of the eggs were laid during April and May. The durations of the stages in the spring life cycle of *A. ruficornis* may be compared with *A. linearis* (following Newton, 1932) and *Cryptophagus acutangulus* (following Hinton & Stephens, 1941), as follows.

TABLE 1.

Duration of eggs, larvae and pupae of the species indicated.

	A. ruficornis	*A. linearis*	*C. acutangulus*
Egg:	4 to 5(?) days	4 to 6 (at room temps.) days	4 to 5 days
Larva:	13 to 20 days	6 weeks max. for eggs and larvae	15 to 16 days
Pupa:	6 to 9 days	—	7 days
Life cycle:	26 to 30 days	—	30 days

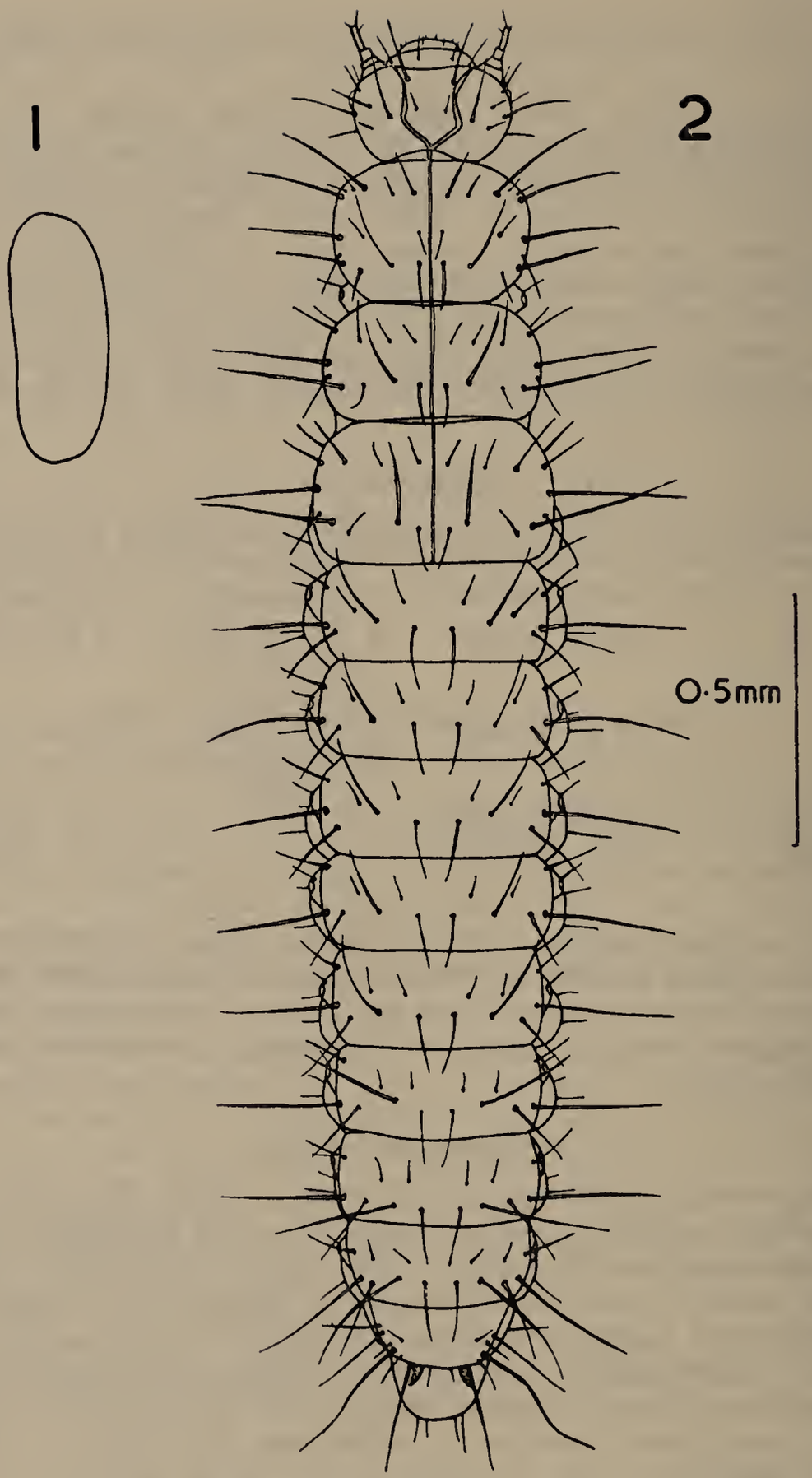
For *A. ruficornis,* the life cycle from egg to adult was completed from April to May at room temperature (about 68° F.). In *A. linearis,* the period was June to August, in the field; and for *C. acutangulus* from January to February, at room temperature (about 68° F.).

The Immature Stages

Owing to the small number of larvae obtained, a histogram of larval head widths, although analysed using Harding's method for small numbers (Harding, 1949), gave inconclusive results (Evans, 1960). It would appear that there are at least three, but possibly as many as five, larval stages. It should be noted that for *Cryptophagus acutangulus,* Hinton & Stephens (1941) described three larval instars, and this is the same for the few other *Cryptophagus* species in which the life history is known (Hinton, 1945).

(i) *The egg* (Fig. 1)

The egg has an elongate form, is 0·5 mm. (or rather less) in length and 0·19 mm. in width. It is rounded at either end, has an opaque white colour and no visible surface sculpturing. Externally it appears to be almost identical with the egg of *A. linearis* as described by Newton, 1932.



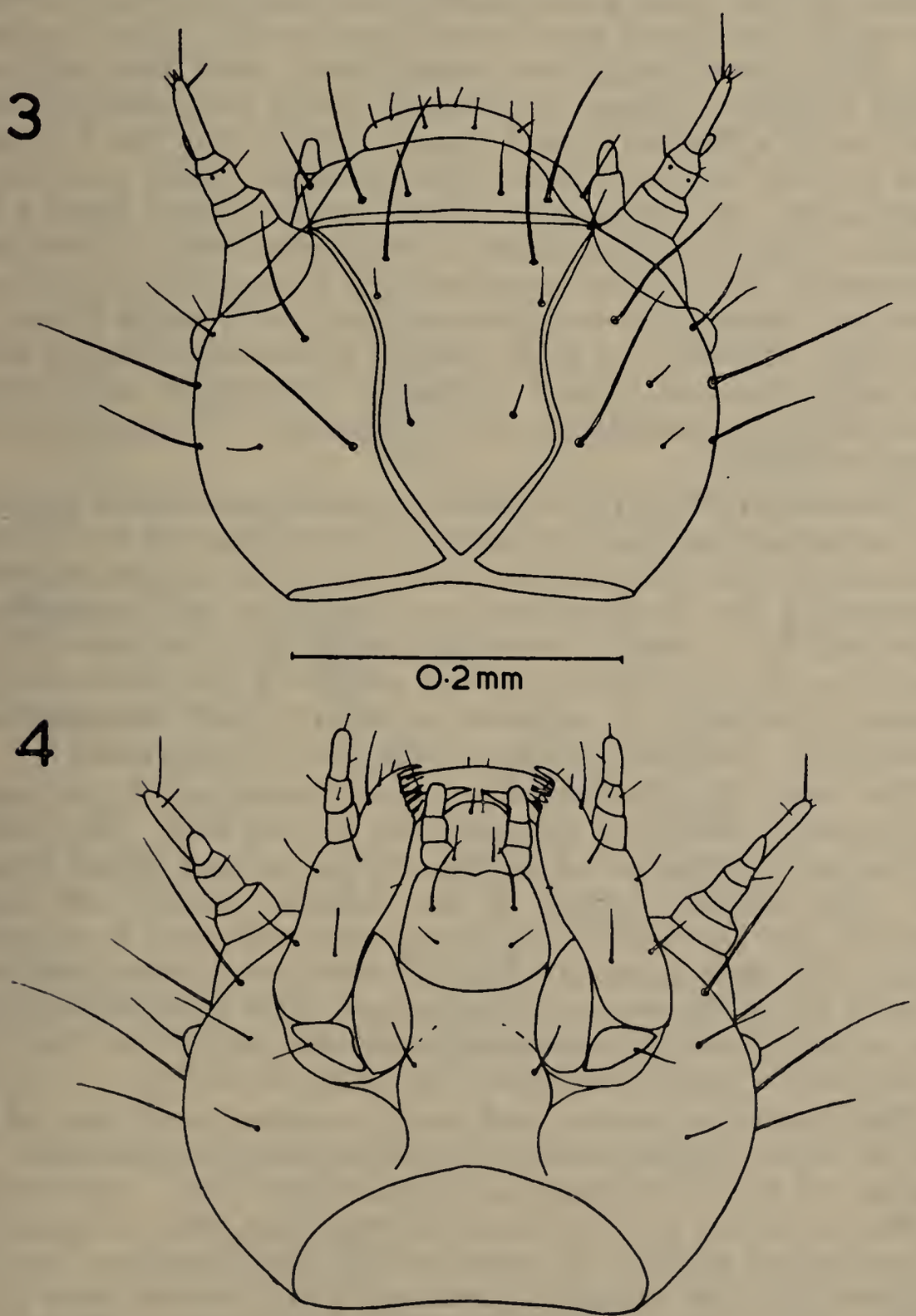
Figs. 1 and 2, *Atomaria ruficornis*.—1, Egg. 2, Last instar larva: dorsal view.

(ii) *The last instar larva*

The full grown larva (Fig. 2) is usually between 2·9 mm. and 3·0 mm. in length, although preserved specimens vary between 2·4 mm. and 3·4 mm. It is about 0·5 mm. broad. The cuticle and underlying organs are opaque and white. Only parts of the head

capsule, the mandibles and the urogomphi appear light brown.

In dorsal view the head appears very rounded (Fig. 3), and is rather narrower than the prothorax. In all the specimens examined the head was 0·3 mm. wide. The head capsule is lightly coloured but the wide dorsal cleavage lines and the gular region were darker. The setal arrangement is shown in the figures (3 and 4). A single large ocellus is present on each side of the head. The three segments of the antennae (Fig. 5A) are lightly coloured basally, and colourless apically. The first segment is rather broader than the second, and about two-thirds as long.



Figs. 3 and 4, *Atomaria ruficornis*.—3, Last instar larva: head in dorsal view. 4, Last instar larva: head in ventral view.

The ventral accessory lobe of the second segment is about as wide as, and one quarter as long as, the third segment. The third segment is about half as wide and twice as long as the second. The setae are as shown in Fig. 5A.

The clypeus bears a row of four almost equally spaced setae, of which the outermost are the largest. The labrum, which is narrower than the clypeus, is nearly straight anteriorly and strongly rounded laterally. It also bears a pair of setae near the midline just in front of the clypeus, and has three pairs of small setae near the anterior margin. One pair lies on either side of the midline and the other pairs are antero-laterally placed. A row of very small setae lies on the ventral labral margin. Each mandible (Fig. 5B) is short, squat and symmetrical, with two large setae arising laterally. There is a larger dorsal and smaller ventral apical tooth. The sub-apical dorsal cutting edge has a series of three or four smaller teeth. The prostheca ends in a pair of strong teeth. The strongly developed molar surface bears a large number of blunt teeth arranged in transverse rows. The stipes of the maxilla (Fig. 5C) is supported by a small triangular cardo. The stipes carries a three-segmented palp and a single biting lobe, the mala. Mesally, the mala bears a series of six strong spines. The apical tooth is turned obliquely downwards and inwards; another more ventral tooth lies sub-apically. The setation is as shown in Fig. 5C.

The labrum (Fig. 5D) consists of a small prementum supported by a sub-quadrate mentum, which is succeeded by an ill-defined submentum. Both the submentum and gular region are weakly sclerotised. The postmentum and maxillae are separated on either side by a weakly developed articulating sclerite (Fig. 4). The prementum is slightly rounded anteriorly and bears two pairs of setae. Laterally it supports a pair of small, two-segmented labial palps. The mentum bears two pairs of large setae.

The head is separated from the prosternum by a pair of ventro-lateral folds and by a median ventral fold. The thoracic tergites are bisected in the midline by the narrow dorsal cleavage line. The median regions of the thoracic tergites are lightly coloured, but the rest of the thorax and abdomen is an opaque white. The mesothoracic spiracle is borne on a lateral projection between the prothorax and mesothorax. It is considerably larger than each of the eight abdominal spiracles (which are also borne on the pleural membrane), and lies more ventrally.

The thoracic segments each carry a rather small pair of legs, each of which ends in a strong, claw-like tarso-metatarsus. The setation of the third leg is as figured (Fig. 8). The thoracic tergites each bear two well-defined transverse rows of setae. On the abdominal tergites the rows are set close together, and this, together with the posterior position of the second seta of the anterior row, gives a more irregular arrangement. The dorsal setae, especially those arising near the lateral margin of the tergite, are much larger and longer than the pleural and sternal

setae (see setal map, Fig. 7).

The ninth tergite (Fig. 6) carries a pair of small, amber-coloured urogomphi. These point upwards and are outwardly directed. The long setae of the ninth segment point posteriorly rather than postero-dorsally as in more anterior segments. The terminal part of the ninth segment consists of the well-developed anal pseudopod.

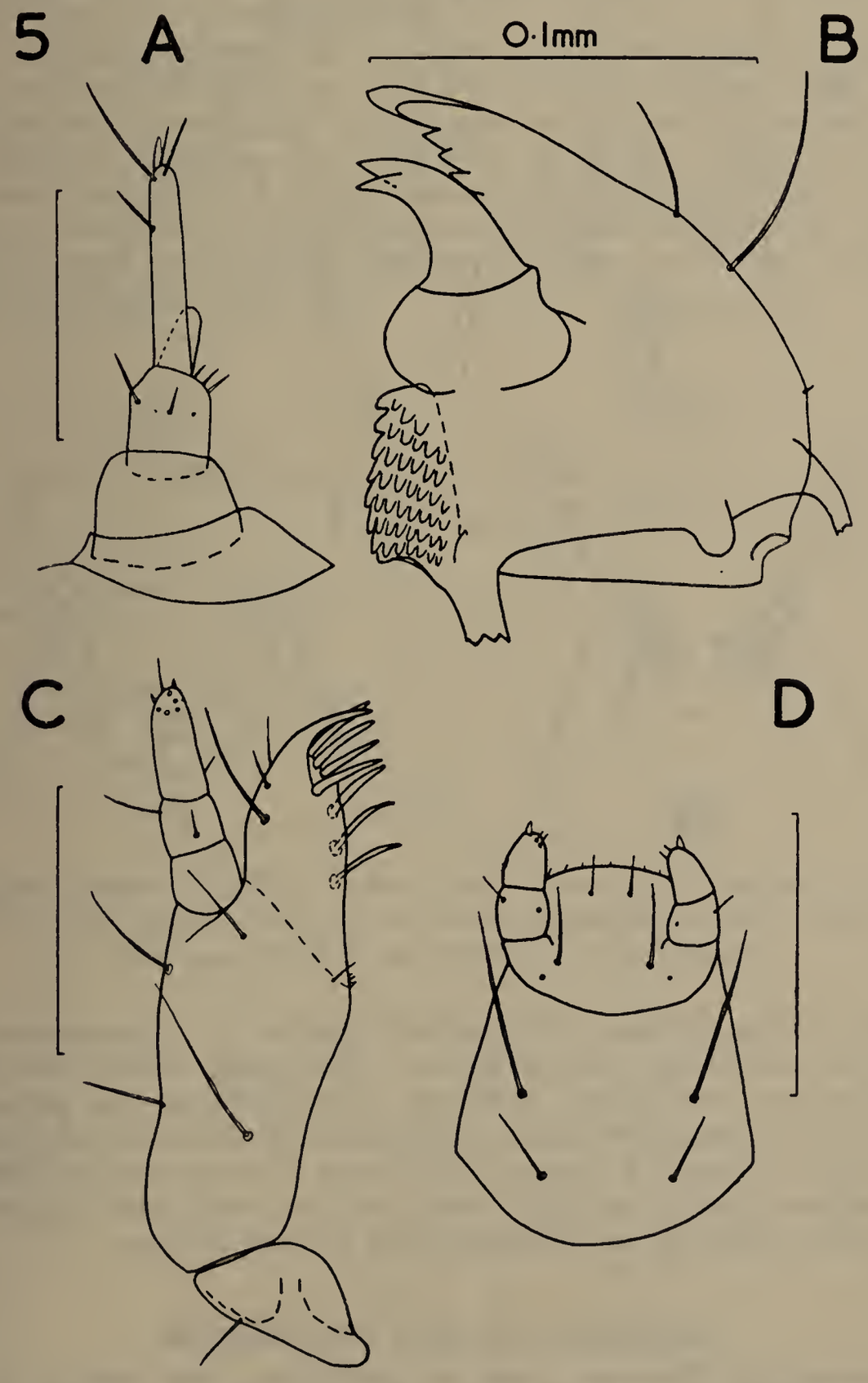


Fig. 5, *Atomaria ruficornis*.—Last instar larva: A, Right antenna, dorsal view; B, Left mandible, ventral view; C, Right maxilla, ventral view; D, Mentum and prementum, ventral view.

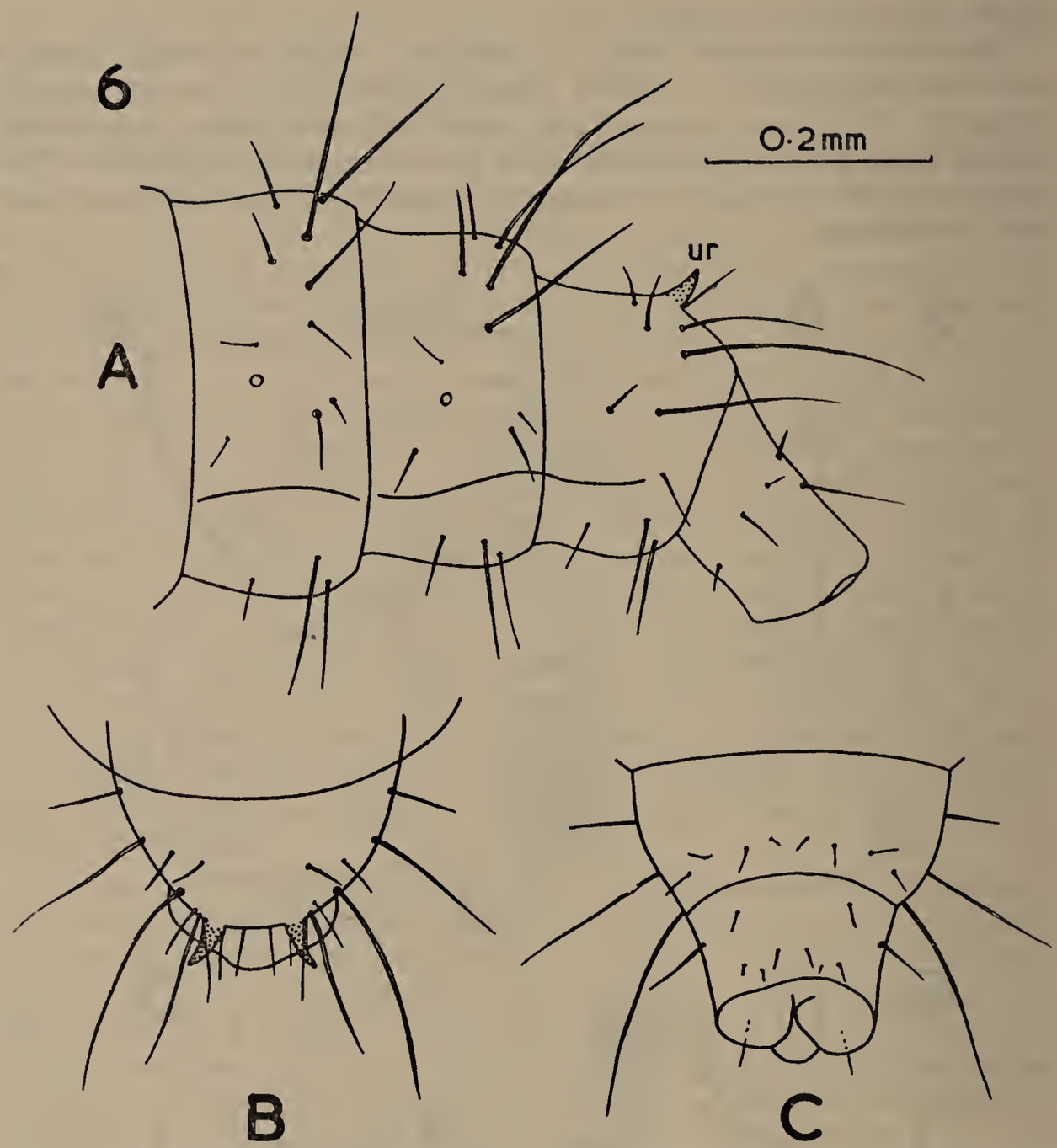


Fig. 6, *Atomaria ruficornis*.—Last instar larva: posterior segments. A, Lateral view of segments seven to nine; B, Dorsal view of ninth segment; C, Ventral view of ninth segment.

Earlier instar larvae. These are similar in proportions and setation to the last instar larvae. The head widths are more variable, but are always wider in proportion to the pronotum than in the last instar larva, and the setae are relatively longer. In both *A. linearis* (Newton, 1932) and *C. acutangulus* (Hinton & Stephens, 1941), the first instar has the head much larger and the setae relatively much longer than in later instars.

Comparison with other Cryptophagidae

Larvae of *Atomaria* may be separated from those of the Cryptophaginae by the presence of two-segmented labial palps in the former, as opposed to the single-segmented palps of the latter. The only comparison that can be made within the genus *Atomaria*

is that between *A. ruficornis* and *A. linearis* (Newton, *l.c.*). *A. ruficornis* differs from the latter as follows:

a. The urogomphi are very small and outwardly directed, whereas in *A. linearis* they are large (supported on processes of the ninth tergite) and are inwardly directed.

b. The third antennal segment is about twice as long as the second, whereas in *A. linearis* the second and third segments are of about the same length.

c. On the abdomen the anterior row of tergal setae is rather close to the posterior row and has the second seta set back, whereas in *A. linearis* the setal rows are clearly separated. On the thoracic tergites, the fifth seta from the midline in the posterior row is fairly large. In *A. linearis* it is very small or absent. Similarly, in *A. ruficornis,* a second prothoracic seta is present (near the midline) between the two setal rows, whereas this is lacking in *A. linearis.*

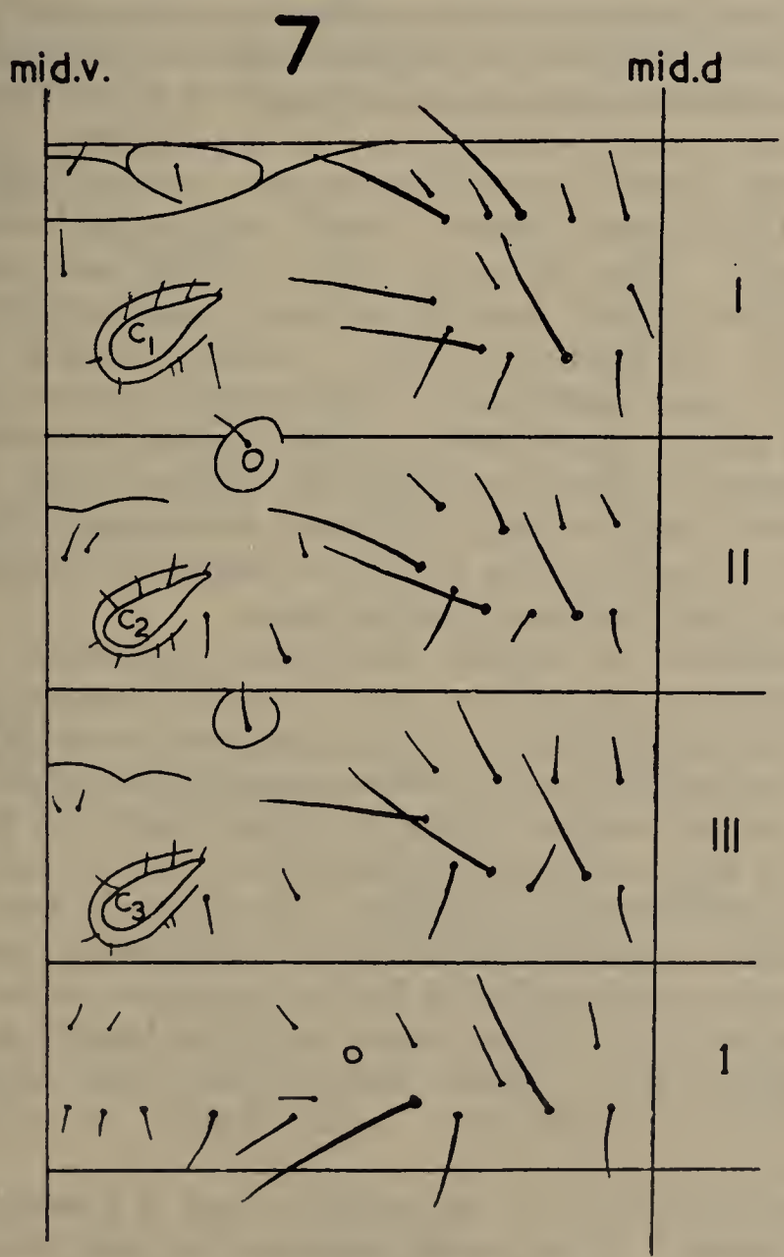


Fig. 7, *Atomaria ruficornis.*—Map of setal arrangement on thoracic and first abdominal segments of last instar larva; shown from the dorsal midline (mid.d.) to the ventral midline (mid.v.).

d. Other small differences can be observed by comparing the map of setal arrangement and the figures of the ninth segment given by Newton (*l.c.*) for *A. linearis* with those given for *A. ruficornis* (Figs. 7 and 6).

(iii) *The pupa* (female: Fig. 10)

The pupa is 1·66 mm. long and 0·73 mm. wide (the base of the pronotum is 0·62 mm. wide), and it is strongly curved dorso-ventrally. The cuticle is uniformly white and shining, with long erect or sub-erect setae which are particularly obvious laterally. The head is either completely hidden in dorsal view, or only the vertex is visible; this depends partly on the degree of curvature of the pupa. In anterior view, a series of eight setae are visible on either side of the head above (posterior to) the antennae.

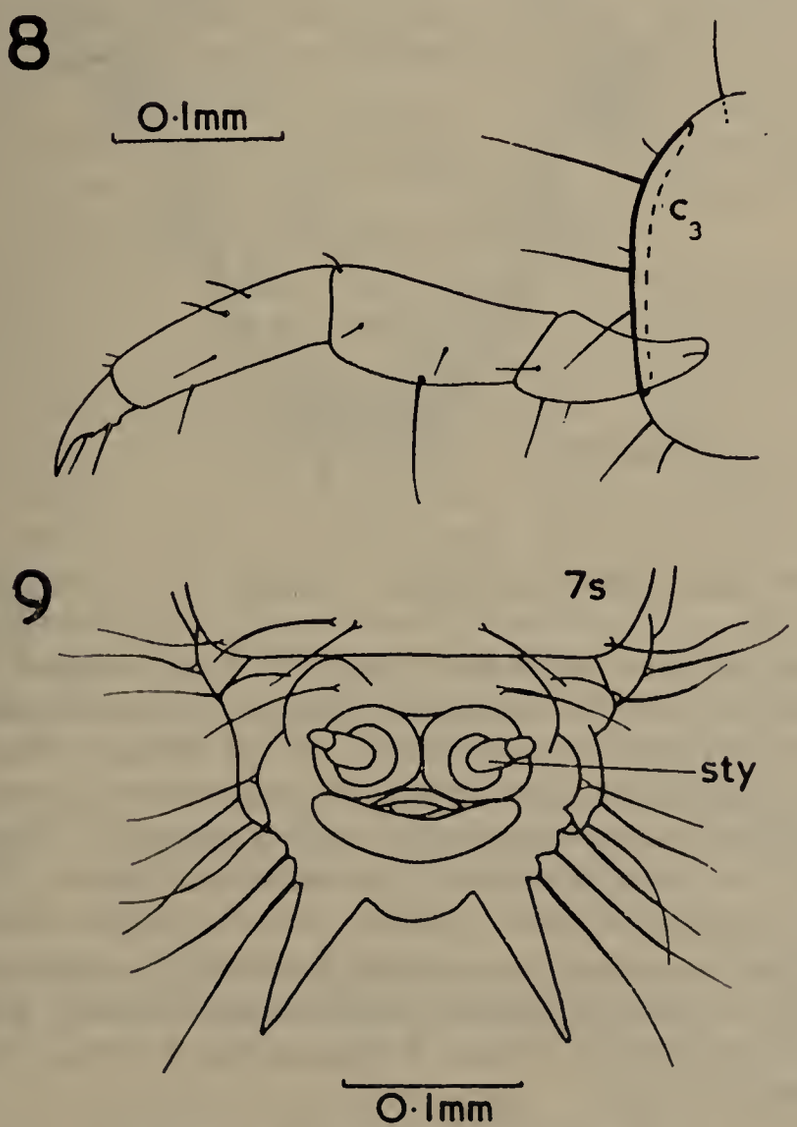
A short seta lies near the midline of the vertex at the same transverse level as a long, more lateral seta (the longest head seta). Two short setae lie postero-laterally some way behind the eye. A long seta lies immediately beside the postero-mesal margin of the eye, and a slightly shorter seta arises a short distance posterior to the antennal base. A short seta lies between the latter seta and the long seta of the vertex. The only seta borne by the cuticle covering the eye arises from it postero-laterally. The clypeus bears a single seta on either side near the lateral margin. The labrum, which forms an almost straight union with the clypeus, has the anterior margin feebly emarginate at its middle. It bears no setae. A single seta is borne by the outer edge of each mandible. The antennae arise together near the midline and extend back to the level of the posterior end of the mesonotum. They are slightly thicker than in the adult. Each segment bears a series of small tubercles. These are most pronounced on each of the last three segments, where they form a transverse row of conical projections.

The pronotum is weakly bisinuate posteriorly, and appears strongly rounded anteriorly and laterally when viewed from above. This is due partly to the depressed anterior angles of the pronotum, and partly to the dorso-ventral curvature of the pupa. Thirteen long setae are borne on either side of the pronotum. They form a series around the anterior and lateral margins and a group of three near the midline. In addition, two setae arising on either side a short distance from the lateral margin lie in an antero-posterior row with the lateral anterior setae. There is a row of six anterior marginal setae, and five lateral marginal setae arise on either side. Three setae arise close together at the posterior lateral angle; the most dorsal of these lies sub-marginally.

The mesonotum bears an anterior and a posterior transverse row of four setae. With the exception of a fairly long seta arising beside the elytron in the posterior row, the setae are all rather short. The elytra extend postero-ventrally to the level of the fourth and fifth abdominal segments. The surface of each elytron

bears a series of low ridges, one of which bears three setae not far from the elytral base. The metanotum also has an anterior and a posterior row of four short setae. The wings extend back with the elytra, and are covered by them. The posterior margins of the anterior abdominal tergites are truncate; the posterior margins of tergites seven and eight are rounded. Tergites one to eight bear a series of seven setae on either side. On each tergite these form an indistinctly separated anterior and posterior row. On the more posterior tergites, the setae become rather longer and more recumbent. The ninth tergite bears a pair of slender, pointed urogomphi.

The first seven abdominal pleurites are visible from above. The first five bear a spiracle dorsally, and the first two bear a single large seta posteriorly. On pleurites three to seven, two large setae are borne near the posterior margin. The metasternum bears a pair of small setae near the midline about half way along the segment. The abdominal sternites one to six bear a pair of long postero-lateral setae on either side. In addition, sternites seven and eight also bear a fairly long seta near the midline on either side. The apical region is shown in ventral view in Fig. 9. In the female, the styli of the ninth segment are visible.



Figs. 8 and 9, *Atomaria ruficornis*.—8, Last instar larva: third leg in posterior view. 9, Female pupa: ventral view of terminal abdominal segments.

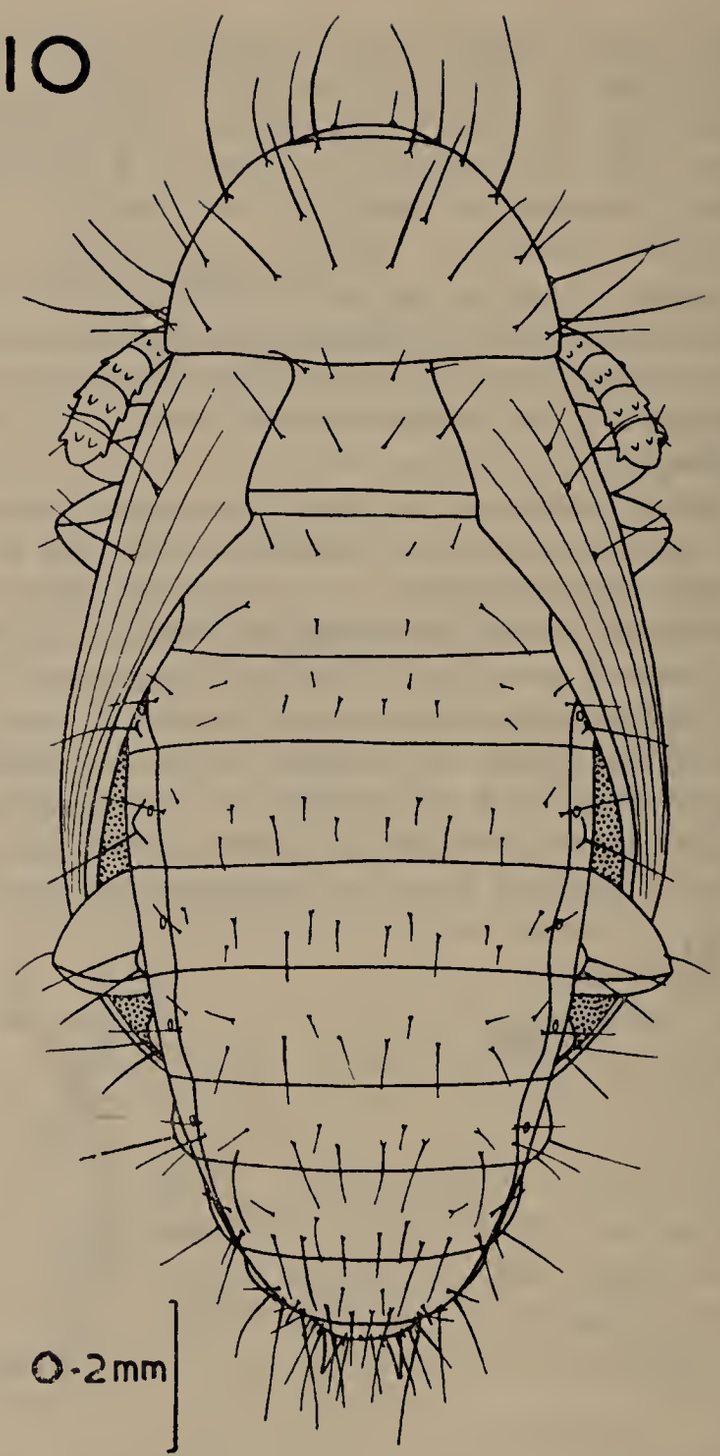


Fig. 10, *Atomaria ruficornis*.—Female pupa: dorsal view.

The tarsi of the anterior pair of legs extend back to the anterior margin of the metasternum, and are separated distally by a distance equal to the length of the tibia. The middle pair of legs lies immediately behind the anterior pair and the tarsi reach about half way along the metasternum. They are rather more widely separated than the anterior tarsi. The posterior pair of legs extends back to the level of the fifth abdominal sternite (with the abdomen curved ventrally), where the claws are separated by a distance equal to the length of the pretarsus.

The male is similar to the female except that it lacks styli on the ninth segment.

Comparison with other species

No other pupae of the genus *Atomaria* have apparently been described, although Hinton (1945) has given descriptions of the

pupae of a number of species of *Cryptophagus*. The most detailed description is that of *C. acutangulus* Gyll. (Hinton & Stephens, *l.c.*). The pupa of *A. ruficornis* can be distinguished from that of *C. acutangulus* (and that of many other beetles) by the shape of the pronotum in dorsal view. In *A. ruficornis,* it is rounded at the sides and is contracted anteriorly, in contrast to the subquadrate pronotum of *C. acutangulus.* The number of setae present on the thoracic and abdominal tergites of *A. ruficornis* is similar to that on the tergites of *C. acutangulus,* and the setal arrangement is similar, although there are three elytral setae in *A. ruficornis* in contrast to the two present in *C. acutangulus.* The pupa of *A. ruficornis* can also be recognised as an *Atomaria* pupa by the proximity of the antennal bases characteristic of the imago.

Discussion of the life cycle

Beetles were active from April to October inclusive, and pairs *in copula* were found during each of these months. Pairing was most frequent, however, in April, May and June, and in October and late September. It was found that in about two-thirds of the males dissected throughout the year the testes were of maximum size and usually contained shining bundles of sperm (Fig. 11). It seems likely that these bundles of sperm were mature as they were always present in males taken *in copula,* and the spermatheca in many females contained a shining mass of sperm. Conversely, in males with half developed testes and in callows, the testes were uniformly dull white.

While (apparently) mature males could be found from April to October, mature females (i.e. containing well-developed eggs) were found only during April, May, the beginning of June, and in October and the beginning of November (Fig. 11). In these months the beetles laid eggs under laboratory conditions. From April to early June, most female beetles contained fully-developed ovaries, often with well-developed eggs. The size of the ovaries was estimated as $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, or fully developed in each female dissected. Differences in the development of the right and left ovaries are indicated by points on the graph between these levels. The average size of the ovaries decreased sharply in June, until in July, in most of the females dissected, the ovaries were less than half size. During August the average size of the ovaries rose but again dropped to half size or less in September. During late September and early October, the average size of the ovaries rose, and many beetles became mature and laid eggs.

The number of callows was recorded in several samples taken throughout the period April to October 1959 (Fig. 11). Although the samples involved were small, it was seen that the major peak of the emergences occurred in late June. This corresponds to a peak egg laying period at the end of May (given a life-cycle of $3\frac{1}{2}$ to 4 weeks) with a gradual increase in egg laying throughout April and May. The small second peak of the emergences occurred

Fig. 11.—Development of ovaries and testes in different specimens throughout the year at the dates shown. "L - - - - - L" indicates dates at which females laid eggs in the laboratory. "C" indicates the numbers of callows (newly emerged beetles) found in samples at the dates shown.

in mid-September, one month after the small increase in the average ovary size. Although the numbers involved were small, it suggests that at least some of the females became mature and laid eggs during August, six weeks to two months ahead of the majority of the females.

The major period of egg-laying and development in *A. ruficornis* is from April to June. The only other species of *Atomaria* of which the life history is known in any detail is *A. linearis* (Newton, 1932). This is a pest of Mangolds and Sugar beet, where it is found during late spring and summer. It occurs in large numbers in June and early July, at which time copulation was observed. The life history apparently lasts not more than six weeks, and full-grown larvae were obtained in early August. Large numbers of beetles have been found in autumn in débris or in the soil (Morris, 1927). Newton (*l.c.*) remarked that there is probably only one brood of *A. linearis* in the year. It is possible that there is only one generation per year in the case of *A. ruficornis,* and that the eggs laid in October gave rise to adults, which did not lay their eggs until the following October. It is not known if the eggs overwinter without further development. Larvae bred in the laboratory from autumn eggs took six to seven weeks to complete their life-cycle, considerably longer than in the spring life-cycle, and emerged during the last part of December.

It seems likely that the generation of *A. ruficornis* laying autumn eggs overwinters. Besides adults of *A. linearis,* other *Atomaria* spp. can be found during the winter in the litter of woodland floors (unpublished observations). Again, of those *A. ruficornis* first found in spring, none have been callows, these only increasing in numbers in May and June. Because of the uncertainty of the fate of the autumn eggs in *A. ruficornis,* it is not possible to say how many generations there are per year. Indeed, if the beetles emerging in May became mature immediately, several generations per year would be possible. This is in contrast to *A. linearis* where the larval and pupal stages occur relatively late in the year; this is apparently correlated with a more seasonal food supply than moulds.

Summary

A method is given of rearing *Atomaria ruficornis* (Marsh.) in the laboratory. The egg, the last instar larva and the pupa are described, and compared with those of related species. The life cycle is briefly discussed.

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Abbreviations to Figures

c_1	first coxa.
c_2	second coxa.
c_3	third coxa.
mid.d.	mid-dorsal line.
mid.v.	mid-ventral line.
7s	seventh sternite.
sty	stylus.
ur	urogomphi.
I	prothorax.
II	mesothorax.
III	metathorax.
1	first abdominal segment.

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